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ABSTRACT

Research indicates that the brain grows in spurts occurring every two years or so and alternating with plateau periods in which the gains due to growth are consolidated. While the number of brain cells no longer increases after the age of about 18 months, substantial increases in the complexity of neural networks occur generally between the ages of 2 and 4 years, 6 and 8, 10 and 12, and 14 and 16. These growth spurts occur at age levels corresponding closely with those of the major stages in cognitive development identified by Piaget. This document provides a basic overview of the current understanding of brain growth periodization and discusses the implications of this relatively new area of study for education from the preschool years through high school. It is argued that many of the failures of education arise from the mistaken notion that brain growth is steady and continous, and from unrealistic expectations that students of a common age and grade will also share the same level of cognitive abilities. (PGD)

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Brain Growth Periodization Research: Curricular Implications for Nursery Through Grade 12 Learning

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Introduction

My personal work as a teacher, curriculum specialist, teacher educator and researcher has focused a continuing fascination with problems which learners experiencing at various points in their progress through the school system. It is not uncommon to observe numbers of highly motivated, achievement-oriented youngsters suddenly come to a screeching halt in their cognitive, "learning tracks." Individual frustration and self-doubt at this dramatic reversal of their previous capacity to learn is not feigned for attention, peer approval or other reasons. In such situations, concerned teachers try a range of approaches which seek to challenge, demand, lower expectations for achievement or move these youngsters into kinds of learning "holding patterns." Invariably, these attempts usually prove futile in moving the learner from a "no-go" to a "go" pattern. In most such cases it seems that such youngsters enter a substantial period during which they lose their capacity to move to higher cognitive levels. At other points, youngsters experiencing no great growth in cognitive capacity suddenly seem to leap into a period of almost unbridled increase in cognitive skill. In these instances the learner seems to make a sudden shift in his "learning gears," largely apart from any new cognitive strategy or expectation on the part of their teachers.

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Teachers accept such change without the curiosity or consternation found in the previous condition cited. This writer's puzzlement over such phenomena has been frustrated by the failure of the past educational literature to provide any key to either situation. This concern over these enigmatic reversals was never answered until circumstances brought about the opportunity to meet and interact with Professor Herman Epstein of Brandies University.

In July, 1976, this writer was asked to attend an educational symposium at which Professor Epstein was to present his brain growth periodization study to educators. Because of the concerns of those hosting this meeting over the dramatic nature of these findings, my role was to be as "devil's advocate" and push for full analysis of these findings. The Epstein findings indicated that the human brain experienced great growth spurts at certain times and virtually no growth at other times. This challenged the traditional supposition that the brain grew on a sort of continuum and that the task of educators was to challenge children on the "cutting edge" of this growth for maximum educational growth. Despite all questions regarding bases of the Epstein findings, the veracity of these facts and their implications for education of children became increasingly obvious. I was convinced of the need for educators to become aware of these scientific findings and so I engaged Professor Epstein in further conversations. He agreed to collaborate in such an effort. Subsequently we have published and orally presented our findings and the implications of these data for education. We are also conducting research to validate these realities in educational strategies and programs to improve learning for youngsters. Our initial efforts have focused upon the middle

grades. The implications of these findings, however, hold great import to education of children at all levels from very early childhood to mature adolescence. It is important to examine these implications for this range of ages as well as to examine the facts of brain growth periodization itself.

The Facts of Brain Growth Periodization

The organization of teaching-learning situations in the American school system reflects a kind of faith in an assumed, constant continuum of mind and thinking capacities of learners during their formal education years. The organization of subject matter for such learning reveals a concern for gross, quantitative growth of learners across their years in the educational system. This existing practice reveals no great concern for changing mental capacities of learners with regard to differences of kind of modality of learning possible at specific ages. While teachers may respond to such changes in learners' thinking capacities within their own classes, expectation for quantitative growth in mastery of information and skill development across the total elementary-secondary program, gives little indication of such awareness on the part of curriculum builders.

While Piagetian findings have had increasing impact in the minds of educational and learning psychological theorists, the program of instruction in the nation's school systems has experienced remarkably little change in view of such findings. This writer contends that the area of brain growth periodization findings may have far more reaching impact on the organization of elementary and secondary curriculum. Indeed, the interface of these with Piagetian findings, may combine to create the development of a public school curriculum far more responsive to the intellectual differences and realities children experience as they progress in their journey from early childhood to complete adolescence.

Brain growth periodization findings refute the idea of a constant continuum of growth of mind and thinking capacities in the development of children. The supporting data for the concept of brain growth periodization come from the interface of research data from the areas of anatomy, biophysics and developmental neurobiology and confirm that the brain, like other organs, does grow in stage-wise fashion. Epstein (1974) identified that stage-wise growth confirms that organs experience highly chronologically predictable growth spurt stages. The incidence of a growth spurt means that the organ is developing the capacity for higher level functioning and the initiation of higher level capacities during that growth spurt. The Epstein findings also confirm periods of alternating growth spurt stages interfaced with growth plateau stages create the pattern of periodization of growth in the brain. Epstein (1977, 1978) has specified the reality of growth periodization of the brain through correlation with data from a range of existing researches.

Eighty-five to ninety percent of youngsters of average and above ability experience periods of great brain growth between ages 3-10 months, 2-4 years, 6-8 years, 10-12 years, and 14-16+ years. Epstein (1979) observes that the first four of these brain growth stages are on the onsets of the classic Piagetian stages. The latter is also on the onset of the identified fifth Piagetian stage researched by Arlin (1975). This is not to assume that, for instance, on the dawn of the sixth birthday, a youngster enters a twenty-four month period of unbridled brain growth which comes to a screeching halt on the eighth birthday. The reality is that eighty-five to ninety percent of these youngsters will experience their personal brain growth spurt period during the age 6-8 years interval.

The Epstein data similarly identify that the same percentage of students experience intervening periods of plateau of brain growth during ages 4-6 years, 8-10 years, and 12-14 years with again, the personal plateau occuring sometime within each of those interval periods.

Before examining the implications of these alternating growth spurt and plateau of growth periods, some consideration of the nature of both growth spurt and plateau periods is in order. The immediate question which comes to mind is the relationship of growth of brain to the function of mind and learning. Epstein (1980) states that cell replication in the brain, as measured by DNA synthesis, terminates by about 18 months, meaning that the last four brain growth stages occur without any increase in the number of brain cells. Epstein contends that this size increase in the brain is accounted for by very substantial increase in protein per brain. For neurons, this increase in protein is manifested in the elongation and branching of axons and dendtites. Thus, there is strong reason to expect a substantial increase in the complexity of the neural networks in each of the last four brain growth stages (ages 2-4, 6-8, 10-12, and 14-16+ years). This could correspondingly express itself functionally in a substantial increase in the complexity of the thinking processes of the brain.

DNA and DNA synthesis has great impact upon intelligence and there is a history of scientific investigation seeking to enhance and augment DNA in the brain. Research shows that pre-natal and post-natal efforts to provide "super diet" will not enhance the DNA ratio or create a "super brain". Evidence that such a manipulation is impossible is overwhelming. However, since diet and stress can diminish DNA and intelligence the imperatives for adequate nourishment of mothers carrying unborn children and the nourishment

of children in the early years of life cannot be overstressed. Research of such deprivation with laboratory animals and the intervention of stress show that DNA and intelligence can be seriously diminished. In observing again the horrors of starvation one sees today in newscoverage in Cambodia, we can be certain that even for those children who physically survive the ravages of starvation, that nation has virtually lost a generation intellectually. Education in developing nations must recognize that an educational system cannot make up for malnutrition of expectant mothers and children in their early years. Adequate nutrition and education are great partners in the future of any developing nation.

Huttenlocher (1979) has established that children at age 2 have higher density of synapses per cubic millimeter of cortical brain tissue than adults. While scientists had previously thought that density of synapses increased with age, his data confirm that the snyapses shift during periods of brain growth. The increase of cognitive ability during the brain growth stages also infers the possibility of the maturation of synapses during the brain growth intervals. Huttenlocher's data was gathered through a special electron microscopy method to perform post-mortem analysis of frontal cortex cells. His findings also confirm that of dendritic growth continues even though the number of snyapses per neuron declines. Thus dendrites continue to expand during the brain growth spurt periods.

Epstein (1980) has found that there is virtually no growth in the brain mass and no significant increase in the complexity of the neural networks during the brain growth plateau periods at ages 4-6, 8-10 and 12-14 years for eighty-five to ninety percent of youngsters. This reversal of the patterns found in the growth spurt periods (age 2-4, 6-8, 10-12, and 14-16+

years) should cause a serious re-thinking of our educational expectations for how and what children can learn during the intervening brain growth and growth plateau periods.

Implication for Schooling

General implications for learning differentiate between those for youngsters during growth spurt intervals and those in growth plateau intervals. Epstein (1977), Epstein and Toepfer (1978) and Toepfer (1979) see that initiation of new and higher level cognitive processes should be successfully undertaken with high probability for success during periods of brain growth. The extension of neural network accompanying this time predicts this possibility. On the other hand, it appears that learning which stresses the continued introduction of new and higher level cognitive processes will be far less successful during the brain growth plateau intervals. The lack of the addition of neural network during these intervals also reinforces this prediction.

Epstein (1977) correlated the existing research of Eichhorn and Bayley (1962) and Shuttleworth's investigation of mental age growth profiles (1939) with the brain growth periodization stages. Head circumference growth correlates highly. The mental age growth profiles indicate similarity of periods of rise and fall in mental age increase with the brain growth periodization stages. Youngsters experience an average growth in mental age as much as 40 months in some of the brain growth stages while growth drops to as low as 7 months in some plateau periods. Thus even prior to the Epstein data, educators should have seen the need to vary expectations for quantitative growth of youngsters among these biennial periods.

The reality of these data gives strong cause to re-think the graded structure of schooling with its expectations for a constant continuum of growth and mastery across the public school years. To displace this approach, thought must be devoted to identifying expectations for growth and progress upon the correlation of data bases fashioned by the Epstein data.

The implication for planning improved learning experiences must initially consider what is happening to the brain during the growth spurt periods. As was stated earlier, considerable change and shifting of synaptic capacities and the extension of the existing neural networks is manifested during the brain growth stages. Epstein (1978) has confirmed that during these periods of increase, youngsters can be expected to develop increased facility to initiate new and higher level thinking skills. Increasing associative capacity should facilitate successful initiation and extension of one's personal profile of more complex cognitive processes. During the intervals of great brain growth, education should realistically challenge youngsters in development of higher level cognitive skills. These higher level skills can be used to learn new facts and information. Thus, the teaching of new facts and information can be attached to increasingly more complex cognitive, thinking skills for the successful learning of both. In retrospect, traditional schooling procedures may have achieved the success shown in the mental age studies (Shuttleworth, 1939) because during the brain growth spurt intervals, 85 to 90 percent of individuals experience the capacity needed to advance successfully to higher level and new cognitive processes while learning new facts and information.

However, the lack of success of traditional schooling in the constant expectation of an achievement continuum is also evident in the mental age

growth data. During the intervals in which plateaus of brain growth are experienced, most students do not have the increasing snyaptic capacity necessary to continue and successfully initiate new or higher level thinking skills. If teaching of new facts and information is attached to the learning of higher level thinking skills during the plateau periods, the facts and information taught at these higher levels may also be unattainable for many learners. To this end, a major re-thinking of learning expectations during the plateau period intervals is critical.

It is important that the findings of brain growth periodizations are not misunderstood or misinterpreted. Brain growth periodization does establish that it is largely impossible for most youngsters to successfully initiate and develop new or higher level cognitive skills during their personal, periods of plateau in brain growth. It does not say that students cannot learn anything during these plateau periods. Youngsters can learn new facts and information with good success during both growth spurt and growth plateau periods. The critical difference is that in the former, new facts and information can be attached to the learning of appropriate new and higher level thinking skills. However, during the growth plateau periods, new facts and information cannot be attached to new or higher level thinking skills. Facts and information are successfully learned during growth plateau periods when they are taught within the existing cognitive, thinking skill profiles initiated by learners during previous growth spurt periods.

The emphasis of successful learning during the brain growth plateau periods then, must be upon the learning of new facts and information through the student's existing profile of learning skills. Attention can also be given to helping students refine, consolidate and mature their range of thinking skills

initiated during their previous period of brain growth. It may well be that nature, in its sequencing of alternating periods of brain growth spurt and plateaus of brain growth, has given us another clue which we have failed to identify. After a period of rapid growth in which the initiation of new capacities and processes occurred, it is important to switch from seeking further vertical growth of new and higher level skills until those previously initiated are fully refined and matured. Thus the learning of new facts and information during the growth plateau intervals can also serve the important needs of learners to mature what they have just initiated before going on to further new and higher level thinking capacities.

The problems of mental and emotional illness in children are increasing greatly. Beane and Lipka (1979) state that success in learning is highly related to the development of positive self-concept and self-esteem. Students who succeed in initiating new and higher level cognitive capacities and learn new facts and information during brain growth spurts are often led into a built-in failure experience during the ensuing plateau period. Traditional expectations for continued growth and mastery of skills and facts are bound to damage both self-concept and self-esteem during these periods. This will be discussed later as the "Turn-Off Syndrome."

The development of differing expectations for quantity and quality of learning experiences by students is essential. However, the need to identify how and when youngsters enter and leave growth spurt and growth plateau periods is of great concern. This is not a phenomenon which occurs for all children at the same exact time. Periods of growth and plateau of growth are experienced by from 85 to 90 percent of youngsters at some point during each of the biennial intervals. Some will experience longer periods of growth

spurt and growth plateau while others will experience these phenomena in shorter time periods. It is important to identify when this occurs if we are to organize more responsive learning environments in schooling across these years.

It almost seems that growth and development of the brain is governed by an evolutionary, biological time-clock. Since youngsters appear to develop new and higher level cognitive thinking skills during the brain-growth stages, what should be the focus of learning during the plateau periods? It well may be that learning experienced during the plateau intervals should focus upon helping youngsters to consolidate, refine and mature the new and higher level thinking skills initiated during their recently completed brain growth spurt period. In refining and finely tuning their existing profile of thinking capacities, students may sharpen their readiness to gain the most from new and higher level cognitive skills achievable in their next brain growth spurt period. At the same time they can learn facts and information during their plateau interval through use of those thinking skills they presently possess and can refine.

The Reality of Cognitive Levels

Epstein (1980) presents an expectation of the percentages of youngsters who can think at particular levels. Figure I shows the percentages of youngsters who can be expected to think at particular levels at a given age. As was stated earlier, the first four of the Epstein stages are the turning point for the classical Piagetian stages while the final brain growth period correlates with Arlin's identification (1975) of a fifth Piagetian stage. In this, we can see that youngsters in early childhood and elementary education

face the task of moving successfully into concrete operational thinking and then maturing that modality from the onset stage.

The middle grades youngster faces the continuing of the maturation of concrete level thinking from the onset of that style and then the movement, in some instances, into the mode of formal operations thinking. As Figure I identifies, the actual percentages of youngsters who can move into formal operations during the age 10-14 years span of typical middle grades programs are surprisingly small. The focus of the high school, then, should be upon the maturation of formal operations capacities for those youngsters at that level and working to help large numbers to move with success into formal operations, particularly during the age 14-16 years brain growth spurt period. The tasks and concerns facing education at each of these levels of schooling are presented as follows.

Early Childhood and Elementary Education

Current identification of parenting needs, particularly for very young children, must identify what kind of family and home tasks could facilitate the best development of youngsters during the age 3 to 10 month brain growth period. However, the expansion of opportunities for pre-kindergarten schools requires consideration of the learning tasks appropriate for youngsters during their age 2-4 years stage of great brain growth. The entire thesis of Montessori learning for children at this age may already identify the learning needs of this age group. The growing need for child day-care centers due to the increase in the numbers of single parents of young children and working mothers should give this aspect of the child's development a high priority. The age 2-4 year old child does have a readiness for intellectual learning during this brain growth spurt. Regardless or how this educational and social

FIGURE I

AGE (YEARS)	PRE OPERATIONAL	CONCRETE ONSET	CONCRETE MATURE	FORMAL ONSET	FORMAL MATURE
5	85	15			
6	60	35	5		
7	35	55	10		
8	25	55	20		
9	15	55	30		
10	12	52	35	1	
11	6	49	40	5	
12	5	32	51	12	
13	2	34	44	14	6
14	1	32	43	15	9
15	1	14	53	19	13
16	1	15	54	17	13
17	3	19	47	19	12
18	1	15	50	15	19

(TAKEN FROM EPSTEIN, 1980)

need may be addressed, we must look more seriously at the implications of these findings for the child as he begins his traditional elementary school experience. The vast majority of American youngsters enter elementary school between 4 and 6 years of age. This biennial period includes the first major plateau stage in brain growth periodization for between 85 and 90 percent of youngsters. Both parents and educators need to recognize that the first experience in elementary schooling occurs at a time when the child usually cannot initiate or develop new or higher level thinking skills to the degree possible during the age 2-4 years stage of brain growth.

The surge of enthusiasm exuded by parents as children begin school and the joy most children finds in school and teachers should not overshadow the reality of our expectations of what children can really learn during this age 4-6 year plateau in brain growth. It seems that we overlook what Froebel, Rousseau, Pestalozzi and others saw as the social learning needs of children at this time. Instead, we launch headlong to manipulating the vertical cognitive growth of children. This is especially true now that many children have had pre-school or nursery school experiences. Too often we view that as having met their socialization needs when in reality they were probably ready for beginning cognitive growth between age 2 to 4 years.

We also may misconstrue the Kindergarten and first grade child's desires to please their teacher and their high motivation to succeed as an ability or readiness for developing new and higher thinking skills. This is an error. Learning between age 4-6 years should develop its cognitive focus from a social learning base. The age 4-6 year plateau period cannot be overlooked. Practices of schooling in past decades with age 4 to 6 years youngsters indicate our unfortunate willingness to overlook other research which might

cause us not to create learning problems at this age. Research in reading readiness has long proven that forcing a child to learn to read prior to readiness will create serious reading problems for many years. Research similarly has shown that if such children without reading readiness are taught through discussion and other activities, they can still learn facts and information. Where reading readiness has not appeared among students until as late as third grade, and where reading instruction has not preceeded this readiness, these students catch up by grade six with students who began reading instruction in first grade.

Conversely, research reveals continuing problems found among those children forced to attempt reading before they have that readiness. Girls experience eye muscle development ten to eighteen months earlier than boys during the age 4 to 6 year interval. Thus girls have greater physical readiness to read in first grade than most boys. The degree to which boys learn poor reading habits over girls may be seen in examining needs for reading remediation among our nation's high schools. In high school, boys require remedial reading by as much as six to one over girls. Thus the brain growth data plateau period in the age 4-6 years period provides strong reason to examine present practices and expectation for cognitive growth during that time.

The practice of early intervention strategies in head start and related programs for disadvantaged youngsters also needs examination in light of the identification of the age 4-6 years plateau period. Examination of research dealing with head start programs for disadvantaged youngsters during this plateau stage indicates that in terms of the massive effort, little lasting cognitive growth has been experienced by these children.

Hunt's examination (1975) of the first decade of such projects indicates they really have been a failure. Brain growth periodization data suggests that youngsters cannot be expected to "catch up" with advantaged children if the intervention, as classic Head Start programs do, is offered during a period of low brain growth. Failure to see the improbability of success of such attempts when offered during a plateau stage lead to dangerous conclusions. Jansen (1969), for instance, postulated the failure of early intervention projects supports theories of the inferiority of minority and disadvantaged groups.

This failure really is due to placing such intervention efforts during a plateau period. Thus, the myth of racial or social class inferiority may be finally dispelled. Hunt's findings showed that when Head Start and other early intervention projects designed to help disadvantaged and minority programs offered during either the age 2-4 years or age 6-8 years brain growth periods, the disadvantaged children caught up with and surpassed their middle class, advantaged age-mates. The findings of brain growth periodization research now appear to provide a factual base for disproving any claims of racial or cultural inferiority among disadvantaged children.

Within the frame of brain growth periodization expectations for learning at the respective age 4-6 years plateau periods and the age 2-4 and 6-8 year brain growth stages, the existing research on early childhood intervention projects takes on greater implication for how and when such efforts should be organized.

Datta (1976) documented the impact of the Westinghouse-Ohio State evaluations on federal policy for early childhood programs triggering bitter confrontation over relative influences of heredity and environment on

intellectual development. The Datta report commented that "few articles on early childhood education written for social policy fail to mention the report (the Westinghouse report) as reasonably conclusive evidence that, if long-term effects on school achievement are the goal, Head Start alone is not the way to achieve it" (p. 161).

Lazar, et. al. (1977) and Weikart (1978) have reported a series of follow-up studies on children participating in some of the major early intervention studies in the early 1960's. These children were in need of less frequent placement in special education settings and were more often in correct "age-for-grade" setting than children without experimental pre-school early intervention experience. However, the gross difference cited by many in continuing intellectual growth from the early intervention projects does not appear to be justified. While change in children's performance into middle and high school may be a hope, it has not yet proven true. This, of course, requires changes in the regular public school program, which have not taken place.

While Hunt (1975) pointed to the success of early intervention programs begun outside the age 4-6 years period over those initiated within that period, Hodges (1978) and Hodges and Sheehan (1978) also observed that perhaps Head Start was too late in starting children at age 4-6 years since major developmental tasks have already been accomplished by that time.

Those who continue to be confident in such efforts must examine readiness of learners for initiating new and higher thinking skills. Traditional age 4-6 years intervention programs have not been able to disprove early criticism. White and his associates (1973) maintained that no consistent picture of success emerged using the criteria of most of the (Head Start) studies,

measures of intellectual competence or school readiness. While modest or strong immediate gains from structured programs were frequent, they were just as likely to erode after children left the experimental programs. The instance of loss among experimental group learners contrasted by subsequent growth by control group learners when they entered their first formal schooling experiences, has been supported by follow-up findings showing no significant differences in favor of the experimental group learners. Earlier, Stearns (1971) noted only the short-term success in even the high quality intervention projects and was puzzled over the lack of sustained growth in favor of experimental children.

The planning of both developmental and remedial as well as intervention programs must carefully assess the readiness for learners in terms of their chronological capacities for initiating new and higher level thinking skills. Likewise, the implications of brain growth periodization add another critical dimension in efforts to define appropriate intervention strategies designed to improve learning during early childhood.

Regardless of the problems of learning expectations for youngsters during the age 4-6 years plateau interval, early childhood education also must respect the realities for initiation of new and higher level skills during the age 6-8 years interval. Again, eighty-five to ninety percent of youngsters will experience a period of great brain growth during a period between ages 6 and 8 years. The planning of learning experiences which challenge youngsters and facilitate their initiation of new and higher level thinking skills and cognitive styles needs to be a keen focus during this time. Piagetian testing is a primary tool in identifying when individual youngsters are ready to initiate these higher level skills in their learning

of facts and information. Sund (1976) and Ankney and Joyce (1974) have provided great help in making such identification.

The staging of cognitive learning must also anticipate the age 8-10 years plateau period in which learning of facts and information should stress the refinement, consolidation and maturation of thinking skills and cognitive styles initiated by most youngsters during their age 6-8 years period. Again identification of when individual youngsters conclude their periods of great brain growth and the adjustments on learning strategies necessary during transitional and plateau periods must be a primary concern in determining the scope and sequence of learning across these years. Traditional learning problem areas encountered during these years must be considered against the readiness of youngsters to move to higher level thinking skills at their respective ages. If nothing else, the problems encountered by so many in traditional problem areas such as "long division" and "multiplication and division of fractions" require careful study of effective grade placement of these tasks in light of the facts of brain growth periodization. Again the issue of readiness to learn content which requires capacity for increasing thinking skill and cognitive style must be central to the organization of content in the curriculum.

Middle Grades Education

The history of middle grades education recognizes the problems of learning found during the age 12-14 years interval. The personal, social and emotional realities of the pubescent metamorphosis (Toepfer, 1973) provide traumatic distractions to academic focus, especially when one considers the wide range of the time of adolescent arrival among emerging adolescents. The lack of clarification and separation of fact and folklore

in the mystique of pubescence has hindered past efforts to draw focus on realistic expectations for intellectual and cognitive progress during these years. While the data have existed for decades, Epstein (1977) correlated these data in physical and mental growth with the age 10-12 and 12-14 years intervals. Again, The Shuttleworth data (1939) indicate that between age 10-12 years, youngsters experience an average growth of almost forty months in mental age while such average growth drops to seven months during the age 12-14 years interval. The interface in the findings among brain growth periodization, mental age growth and head circumference (Eichhorn and Bayley, 1962) points clearly for the need to re-examine existing middle grades practice in terms of expectations and strategies for the age 10-14 year population. A separate focus and emphasis in each of the age 10-12 year and 12-14 year components of the middle grades period appears essential. This writer (1979) bases his concern from observation and work in the middle grades throughout his career. Youngsters who can learn new facts, skills and information during age 10-12 years often seem to lose this capacity during their age 12-14 year period. Despite effort and concern, achievement drops severely. It seems important to consider an observation by Epstein that one should never give a learner an input for which the necessary receptor has not been developed. In that sense, we know that during the age 10-12 years interval, eighty-five to ninety percent of youngsters will experience a brain growth spurt with substantial increase in neural network. During this time we observe that youngsters can both learn new facts and increasingly higher thinking skills and cognitive processes. An anology from baseball suggests that during such times, teachers can "pitch" the new facts and information in an expansive "strike zone." The youngster's increasing neural capacity

means that new facts can be learned through reasonably increased thinking and cognitive skills. Thus the learning of new facts and information can be successfully attached to the learning of increasingly higher or new cognitive processes during the brain growth spurt experienced during the age 10-12 years interval. The extension of the same anology into learning strategies during the ensuing age 12-14 years growth plateau period means that teachers must now "pitch" new facts and information within a fixed "strike zone." With the lack of increasing neural capacity during the brain growth plateau experienced at a time during the age 12-14 years interval, new facts and information can be learned most effectively when "pitched" within the existing profile of skills initiated or developed by the youngster during his completed brain growth period. The learning of new facts and information as well as the refinement, consolidation and maturation of thinking skills and cognitive processes initiated during the brain growth period will be facilitated. The problems of academic achievement found in the age 12-14 years interval as opposed to a lower incidence of these conditions in the age 10-12 years period lead to a frightening observation. Perhaps such "over-challenge" in terms of moving to higher cognitive processes and thinking skills in teaching strategies during the age 12-14 years interval builds in a "no-win" situation for large numbers of students. In such "over-challenge", not only is the movement to new and higher level thinking skills and cognitive processes unfeasible for a majority of youngsters; their learning of new facts and information becomes cumberson and difficult, if not impossible. In like measure, challenge at a realistic level is not present and opportunity to refine, consolidate and mature existing thinking skills and cognitive processes is seriously handicapped.

The examination of these conditions in the middle grades makes it imperative to identify the development of children in terms of their thinking capacities during the alternating growth and plateau stages. The research of Shayer and his associates (1976, 1978) has identified that the percentages of children showing mature concrete operations or higher levels increase only at the ages of the brain growth stages. This reveals a strong correlation of thinking level change to the appearance of new complexity in the neural networks manifested during the brain growth stages. Epstein (1979) reports the distribution of percentages of youngsters at thinking stages as it has impact for youngsters in the American educational setting. (See Figure I.)

The occurence of the brain growth plateau period at a time within the age 12-14 years interval should cause us to predict little increase in intellectual abilities in that period. As Epstein (1979) observes, data from Figure I reveal that, indeed, only a small minority of children could have shown any change in level during that period. The capacity to develop formal operations during this time is revealed as achievable for such a small number of youngsters in Figure I, that even at age 14 years, seventy-six percent of learners are still unable to handle material presented at the level of formal reasoning. As Shayer (1976, 1978) has shown, even the top twenty percent of youngsters at age 14 years will show thirty percent of that group who do not display formal operations. Epstein (1979) again observes that this is not surprising since IQ is related mainly to speed of learning while cognitive level is related to style of learning.

It well may be that the brightest of our middle school youngsters are not learning at formal reasoning levels as much as they are exercising

gross memorization of massive bodies of data and procedures. The organization of considerable middle grades learning tasks unfortunately lend themselves too much to memory-recall than explicit demonstration of problem-solving by learners.

Research in school settings is needed to provide data which tests the implications for middle grades education suggested here. Where teachers have been prepared to respond in terms of the cogntive levels actually achieved by learners during the age 12-14 years period, learning of facts and information surpassed the control settings in which the typical middle grades teaching strategies were utilized. It appears that when middle grades teaching strategies are based upon cognitive levels and capacities of learner, information is learned more effectively and that learners have opportunity to consolidate, refine and mature their thinking skills initiated during their previous brain growth stages. There is also some suggestion that when given alternatives of cognitive level placement in discussion with teachers, learners will self-select their actual cognitive level with a high degree of accuracy. These assumptions require validation through experimental-control investigation in school settings.

In reflecting upon the data in Figure I, it is important to consider the implications of IQ for these realities. Epstein (1979) has stated that it is important to recognize that IQ refers to the rate at which one learns something new and should not be confused with one's cognitive level or style of thinking. Further concerns about differences among average and high ability students must consider the findings of Webb (1974). His work with large numbers of gifted youngsters between age 6-11 years indicates that the incidence of formal reasoning is so limited, even in this select population,

that the data on youngsters shown in Figure I holds true for high ability students as well.

Examination of middle grades practices reveals an emphasis upon formal operations level teaching to a far greater degree than that shown by data from Figure I. Programs in grades seven and eight, during which time most youngsters experience their age 12-14 years time-frame, appear to seriously overshoot the cognitive capacities of large percentages of learners. Assessment of teacher expectation and cognitive level of materials and strategies utilized between age 12-14 years is critical in defining realistic expectations for intellectual growth as the result of learnings offered in school during that interval.

A final implication for the middle grades lies in the incidence of sexual dimorphism found between boys and girls at age 11-12 years and at age 14-15 years. Epstein (1978) points out that between age 11-12 years, the second half of the age 10-12 years brain growth interval, girls experience a two-to-three fold advantage in brain growth over boys. The reversal of this phenomenon occurs in favor of boys between age 14-15 years. This writer (1980) stated that it could be hypothesized that girls need a different kind of curriculum at that age. The success of boys over girls in study of analytical and theoretical areas beginning at age 14 continues through higher education. The resultant success of males over females in the more theoretical or abstract professions is an enigma in terms of the advantage in intelligence females possess over males.

Neurology maintains that if newly developed capacities are not challenged, they tend to atrophy. Since school curricula introduces the serious study of analytical and theoretical areas between age 14-15 years, the following

questions arise. To what degree is the success of boys over girls in these areas due to the fact that instruction takes on a serious focus at virtually the same time when boys experience a two-to-three fold advantage in brain growth over girls? Also, to what degree is there causality in that girls do not begin such study until almost three years after they experienced a similar advantage in brain growth over boys? Does the possibility of atrophy of this capacity in girls have any relation in the eventual success of males over females in study in these areas or entry into analytical or abstract professions? Certainly a number of working hypotheses can be developed here which lend themselves to experimental study in curriculum development and learning strategies within the middle grades setting.

The Age 8-10 and 12-14 Years Plateaus

It is interesting that the age 8-10 years plateau period does not show any major cognitive achievement difficulties for children during that stage. It is this author's assumption that the dominant pattern of self-contained classroom environments at this level of schooling facilitates the teacher, as a generalist, looking at students holistically during this plateau period. From this perspective, teachers can make internal adjustments in learning objectives and placements at this time. The problems of the 12-14 years plateau, by contrast, may have a good deal to do with children entering an educational organization where they are taught by subject specialists rather than generalists. Subject specialists see them only during short periods rather than over the school day and deal with them only through a single subject matter area.

During the age 8-10 years time frame then, the child has the advantage of learning from a teacher, who as generalist sees him as a whole person

and integrates his learning in several content areas in a self-contained setting. In addition, the vast majority of these children are still pre-pubescent and not entering the traumas of emerging adolescence which many will begin during the age 10-12 year time and virtually all will experience between age 12-14 years. Thus, the brain growth plateau period experienced between age 8-10 years, unlike the next one experienced between age 12-14 years, does not have major focus upon the tasks of pubescent metamorphosis. A third factor makes the experience of the plateau between age 8-10 years far less difficult than the subsequent one during age 12-14 years. This deals with the modes of thinking performed during both of these periods. In the former, the vast majority of youngsters are moving upward within their development of concrete operations thinking skills. Their movement is frequently from initiation to maturation of this mode of thinking. On the other hand, the plateau period experienced between age 12-14 years comes at a point where the maturation anticipated is movement from concrete operations skills to formal operations, a totally new mode of thinking. The initiation of even beginning formal operations skills is a far more complex task than the maturation of already initiated concrete operations skills. While not causual in any definitive sense, this author offers these earmarks of the school experience and thinking progress of youngsters as contributory to why the age 8-10 years plateau period in brain growth is not replete with the cognitive learning problems experienced during the age 12-14 years plateau period.

Secondary Education

The High School must recognize the fact that amazingly few youngsters move from concrete to formal operations during its experience. (See Figure I.)

In fact there is only an increase of 14 percent during this time. This is all the more critical if one considers the prime time for movement to higher levels to be what brain growth periodization suggests. That means that the high school has a brain growth period between age 14 to 16+ years followed by plateau and maturation setting. While problems specific to the high school need to be focused, it also must be recognized that, as the terminal schooling unit for most, the high school also inherits problems created at earlier schooling levels.

The problems of the plateau experienced during age 12-14 years prompted this writer to investigate what happens to youngsters learning during that time as it might impact progress in the high school. Logically, one might expect to see large numbers of "turned-off" learners in the age 12-14 years period make a positive reversal during their age 14-16+ years brain growth experience in the high school. Shayer and his associates (1976, 1978) found that almost 30 percent of high ability youngsters do not make such a reversal. This, as reported and discussed by Epstein (1979), prompted this writer to examine this condition in an American sample. The initial reporting of this "turn-off" syndrome by this writer and Epstein at the 1979 conference of the Association for Supervision and Curriculum Development was carried in Education U.S.A. (March 12, 1979).

The decision to study this was prompted by the observation that there appeared to be no mass "redemption" of high school youngsters during their age 14-16 years experience. Instead, large numbers of them appear to become increasingly cynical, apathetic and hostile in classroom setting at this level. This seemed to indicate that large numbers of youngsters did not, or were unwilling to use this time to initiate new and higher level thinking

skills, as reflected by statistics of increasing drop-out rates and mediocre academic performance.

To this point, data have been gathered from a large sample in Western New York. (See Figure II) This data were presented briefly in Toepfer (1980) but not specifically analyzed. Subsequently, data have been gathered from similar samples of students in both metropolitan Buffalo, New York and Atlanta, Georgia. These data were gathered from cumulative records of students who completed high school or dropped out within the past year. Where possible, data were gathered in four IQ ranges and identify students in each category as follows. In each location, 250 student records in each IQ range were selected who had nothing short of consistant high success in learning in school prior to age 12. This was measured as having no grades lower the B- at any point in their cumulative record prior to age 12. Identification was then made of the numbers of students in each IQ range who experienced their first problems of serious achievement in school between age 12 and 14 years. Serious achievement was taken to be achieving grades lower the C-. The data presented in Figure II, III, and IV indicate the serious nature of this problem. Likewise, the similarity of these data gives reason to consider the "Turn-off" Syndrome as a wide-spread occurrence.

The incidence of this initial school failure during age 12-14 years and the high numbers of youngsters who cannot or do not reverse this initial low achievement in their remaining high school years is staggering. The later samples were gathered in two different regions. In the data presented in Figures II, III, and IV, the dramatic increase in such problems experienced in the higher IQ ranges over the lowest one in all three samples was totally unexpected. No reason is offered beyond the following possible considerations.

FIGURE II

THE "TURN-OFF SYNDROME." PATTERNS OF STUDENTS IN WESTERN NEW YORK STATE, 1978

IQ RANGE	90-100 IQ	100-110 IQ	110-120 IQ	120+ IQ	TOTALS
(I) NUMBERS OF STUDENTS WITH NO GRADES BELOW B- PRIOR TO AGE 12	1,000	1,000	1,000	1,000	4,000
(II) NUMBERS AND PERCENTAGES OF BOYS AND GIRLS IN (I)	407/593 41%/59%	411/589 41%/59%	419/581 42%/58%	432/568 43%/57%	1669/1331 42%/58%
(III) NUMBERS AND PERCENTAGES OF STUDENTS FROM (I) EARNING FIRST GRADES OF C- OR LOWER BETWEEN AGE 12-14 YEARS	243 24%	342 34%	358 36%	298 30%	1241 28%
(IV) NUMBERS AND PERCENTAGES OF BOYS AND GIRLS IN (III)	141/102 58%/42%	207/135 60%/40%	214/144 60%/40%	182/116 61%/39%	744/497 60%/40%
(V) NUMBERS AND PERCENTAGES OF STUDENTS FROM (III) WHO CONTINUE TO EARN GRADES OF C- OR LOWER IN REMAINING SCHOOL YEARS	181 74%	281 82%	312 87%	221 74%	995 80%
(VI) NUMBERS AND PERCENTAGES OF BOYS AND GIRLS IN (V)	114/67 63%/37%	176/105 63%/37%	195/117 63%/37%	137/84 62%/38%	622/373 62%/38%

FIGURE III

1980 DATA FROM BOTH BUFFALO AND ATLANTA IN 90-100 AND 100-110 IQ RANGES

IQ RANGE	BUFFALO 90-100 IQ	ATLANTA 90-100 IQ	BUFFALO 100-110 IQ	ATLANTA 100-110 IQ
(I) NUMBERS OF STUDENTS WITH NO GRADES BELOW B- PRIOR TO AGE 12	250	250	250	250
(II) NUMBERS AND PERCENTAGES OF BOYS AND GIRLS IN (I)	117/133 47%/53%	115/135 46%/54%	119/131 48%/52%	121/129 48%/52%
(III) NUMBERS AND PERCENTAGES OF STUDENTS FROM (I) EARNING FIRST GRADES OF C- OR LOWER BETWEEN AGE 12-14 YEARS	64 26%	66 26%	79 32%	80 32%
(IV) NUMBERS AND PERCENTAGES OF BOYS AND GIRLS IN (III)	41/23 64%/36%	45/22 66.7%/33.3%	47/32 59%/41%	46/34 57.5%/42.5%
(V) NUMBERS AND PERCENTAGES OF STUDENTS FROM (III) WHO CONTINUE TO EARN GRADES OF C- OR LOWER IN REMAINING SCHOOL YEARS	47 73%	50 76%	64 81%	65 81%
(VI) NUMBERS AND PERCENTAGES OF BOYS AND GIRLS IN (V)	28/19 60%/40%	32/18 64%/36%	34/30 53%/47%	34/31 52%/48%

FIGURE IV

1980 DATE FROM BOTH BUFFALO AND ATLANTA IN 110-120 AND 120+ IQ RANGES

IQ RANGE	BUFFALO 110-120 IQ	ATLANTA 110-120 IQ	BUFFALO 120+ IQ	ATLANTA 120+ IQ
(I) NUMBERS OF STUDENT WITH NO GRADES BELOW B- PRIOR TO AGE 12	250	250	250	250
(II) NUMBERS AND PERCENTAGES OF BOYS AND GIRLS IN (I)	116/134 46%/34%	113/137 45%/55%	122/128 49%/51%	123/127 49%/51%
(III) NUMBERS AND PERCENTAGES OF STUDENTS FROM (I) EARNING FIRST GRADES OF C- OR LOWER BETWEEN AGE 12-14 YEARS	83 33%	82 33%	74 30%	76 30%
(IV) NUMBERS AND PERCENTAGES OF BOYS AND GIRLS IN (III)	51/32 61%/39%	51/31 62%/38%	41/33 55%/45%	43/33 57%/43%
(V) NUMBERS AND PERCENTAGES OF STUDENTS FROM (III) WHO CONTINUE TO EARN GRADES OF C- OR LOWER IN REMAINING SCHOOL YEARS	70 85%	70 85%	55 74%	54 71%
(VI) NUMBERS AND PERCENTAGES OF BOYS AND GIRLS IN (V)	41/29 59%/41%	43/27 61%/39%	28/27 51%/49	28/26 52%/48%

Perhaps youngsters in the 90-100 IQ range fared better because they were more highly selected from others in their own range than was true for learners at higher ranges. Also, their lower entry into achievement difficulty between age 12-14 years may be due to the fact that teachers tend not to "overchallenge" students of lesser ability and may have lower expectations for students in that IQ range. The possibility of extreme over challenge in the higher ability levels is interesting to ponder. The highest incidence of problem was in the 110-120 IQ range. This could be due to over challenge by parents and teachers who consider these youngsters as "almost gifted" and many believe that with a little more effort, they could do as well as many of the 120+ IQ students. Still, the number of 120+ IQ students who initiate achievement problems between age 12-14 years approximates the data gathered by Shayer (1976).

The possibility of the damage done by over challenge during the age 12-14 plateau period is a possible interpretation. The problems and tasks of the pubescent metamorphosis, the shifting to a different schooling environment, the move to a subject-centered educational approach, all may make the nature of this part of the middle grade transformation extremely brittle. The fact is that once problems in achievement appeared during this interval, the high school had poor success in helping large numbers of learners reverse this pattern.

In light of data from these three samples, the problems of remediation as well as development of learning for the high school are revealed to be serious and complex. Likewise, the high school has to recognize that, in terms of data from Figure I, only an approximate quarter of age 14 year students have the readiness or capacity to learn at formal operational levels. Thus the

high school needs to seriously re-examine its philosophy, methodology and content and orient its program to work with a predominance of youngsters at concrete operations levels. The lip service schools give to "beginning with the child where the child is" must be dramatically translated into action. The high school must consider the facts of brain growth periodization and the actual numbers of youngsters at the reality of their individual cognitive levels with great sobriety. Whether these problems are inherited or not, the high school must adjust to these realities just as education at early childhood and middle grades levels make similar efforts.

Conversations with high school students in the age 14-16 year age group presently faring poorly in achievement following their first serious problems of achievement in their age 12-14 experience likewise has proven sobering. While one may attempt to explain the possibilities of over challenge and that they now are at a time where "catch-up" is possible, most are cynical. Many consider they have grown "stupid" over the past two years. Others are so disgusted with their poor results when they have tried that they prefer not to try again and experience failure. The lack of hopefulness and the disdain expressed for school among those interviewed leads this writer to consider that the poor achievement may be a personal decision. In deciding not to try and reverse this experience, youngsters indicate that the "turn-off" to learning is real and an emotionally-laden decision. It appears that resilience to overcome this dramatic personal failure after a previous record of successful capacity prior to age 12 is very low. The instance of reversal of this initial difficulty between age 12 and 14 is revealed in data in Figures II, III, and IV. The problem is consistent among all four IQ ranges. The

completion of this area of study holds strong implications for re-thinking the delivery system of the middle grades-high school continuum if education across those levels is to improve its success in this regard.

Identification of Student Cognitive Styles and Thinking Levels

Any efforts to reorganize schooling, develop more appropriate learning strategies, develop more responsive curricula and tactical instructional activities must be based upon the identification of individual learner capacities in group, class and local school settings. Such testing must lend itself to group testing at the beginning of semesters or school year for beginning placement in appropriate learning levels and groups. This will allow teachers to further test youngsters as their behavior indicates they come to plateaus or leave them. The ultimate objective in the development of testing means is to be able to respond tactically and as immediate bases as possible.

This writer does not mean to suggest the possibility of grouping based on cognitive thinking level. The problems of eletism seen in separation of students alone does not recommend this. Since youngsters are gregarious and choose friends and learning and age-mates on a variety of bases, classes probably should include ranges of thinking styles. Few of us choose acquaintances on the basis of a common thinking style! In a class setting, perhaps the teacher should present new material on the thinking level of common denominator for the group. This is not "boring" for higher-level thinkers. They simply have a larger range of functional cognitive styles among which they can move. If new material is presented to the group at-large on such a common thinking denominator level, then small group activities can seek to function on the cutting edge or leading level of thinking skills

and styles of appropriate sub-groups of learners. Here appropriate new and higher level skills can be initiated or those at the high level in the plateau can be refined, consolidated and matured.

Teachers should look to learner behavior and change in behavior to guide when possible additional testing may be of help. If a youngster who has been in a plateau and learned new facts and information successfully when presented within a set range of existing thinking levels becomes bored or distracted, perhaps this behavior may indicate a change. Such behavior change could mean the youngster is leaving a plateau and entering a period of transition or a brain growth spurt stage. Tactical testing means would be helpful to the teacher in making such a determination for adjusting the learning strategies and sub-group arrangements for such a child. Likewise, a youngster in a growth stage who has been able to initiate reasonably increasing thinking skill levels may suddenly run into achievement problems and demonstrate frustration at this new inability to progress as he was formerly able. This again might suggest the use of testing to confirm the termination of a brain growth stage and the need to re-direct learning arrangements for such a youngster.

The refining of instrumentation to identify cognitive levels continues. The work of Sund (1976), Ankney and Joyce (1974), and Burney (1974) have been of great help in a number of experimental settings. Testing developed by Shayer (1976, 1978) and the continuing separate efforts of Shayer, Arlin, Anton Lawson and John Renner all promise to make continuing strides in providing educators with more effective testing instrumentation. This progress is critical to develop more effective continuing research in this field as well as to facilitate classroom teachers in organizing more responsive

learning environments and experiences for youngsters throughout the elementary-secondary educational spectrum.

Competency-Based Learning: Some Cautions

As the aura of recrimination of social institutions continues to spread across the nation, we must recognize that historically, times of economic reversal have precipitated such a mood change. Present circumstances, accompanied by the "back-to-basics" rubric have caused us to seize upon the recurring theme of minimum competencies for learning at various school levels. This writer does not disagree with the concept of minimum learner competencies. The critical issues are: who determines these and how do we arrive at realistic, achievable standards?

In many states of our nation there is discouraging evidence that minimum competencies are being developed largely upon expectations for quantitative growth of skills. The constancy of these expectations appears to pay little heed to differences of learners at various points during the elementary-secondary school continuum as it would relate to readiness or differentiation of capacity to learn across these years. The furthering of such mass quantitative growth expectations will achieve only the creation of "no-win" situations for learners at various points in their development. The realities of the alternative periods of brain growth spurt and brain growth plateau periods as established by the Epstein brain growth periodization data must be studied carefully in defining minimal competency expectations. Such competencies need to respond as learners experience alternating age frames in which expectations for cognitive skill development vary. Thus the development, placement and interpretation of criterion-referenced and other standard tests of student achievement must reflect the facts of brain growth periodization.

The language in tests must reflect the cognitive levels found at the age of students tested and should be responsive to the realities of brain growth spurt or plateau in brain growth predictable at those ages.

Failure of the development of minimum competency expectations will not only doom the survival of the concept, but prove punitive and damaging to children. As minimum competency education succeeds or fails in the early childhood level, so shall it fare at succeeding levels in the public schools. The positive goals to develop minimum competency education into a viable, supportive practice are truly important. They can succeed only if they are based in the realities of the kinds of competency and skill expectations that can be realistically formulated in terms of differing capacities of youngsters to learn and grow at differing periods of brain growth.

Conclusion

Public education is facing a number of staggering challenges, some educational and some social. In the case of the latter, the emancipation of women and the need for increasing numbers of both parents to work to provide financial support for family life brings a common need from two different causes. The sixty-eight percent increase in the number of working mothers since 1970 brings a necessity to pre-school environment for children not previously known. The ninety-six percent increase in divorce in the nation in the same period and the incidence of single parent situations further establishes the necessity to look not only at day care and maintenance but at education for large numbers of pre-kindergarten age children. In the case of educational changes, the re-thinking of strategies for early intervention projects and developmental learning approaches for all young children must

examine the times at which learning in general and cognitive dimensions can be most effectively organized. The issues of responding to the learning needs of youngsters throughout their elementary, middle grades and high school experience were never more critical. In the face of changing patterns and environments of life during these years, educators must respond in terms of how children learn at different ages.

In the long run, the facts of brain growth periodization suggest we examine and identify the times at which youngsters develop readiness to move on to higher levels of cognitive functioning. Goals of humaneness, effectiveness of learning and intellectual growth can best be served if youngsters are challenged when they possess such necessary readiness. It is submitted that the scientific fact of brain growth periodization as defined by Epstein must be studied carefully in making such decisions about how and when the nurturing and education of children in the kaleidoscope of educational and social change can best be organized. If such decisions are made without the careful study of when young children are ready for experiences of cognitive and total learning and growth, we shall have doomed our schools at the middle and secondary grades to the remediation and solution of problems which we ourselves may well have created for children. In assessing expectations for learning and the demands of existing curricula across the Nursery - Grade 12 spectrum we can identify areas of poor fit and need. Against this introspection we can then frame more realistic expectations for learners at all stages and develop curriculum which is far more responsive and effective.

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